Fig. 1A

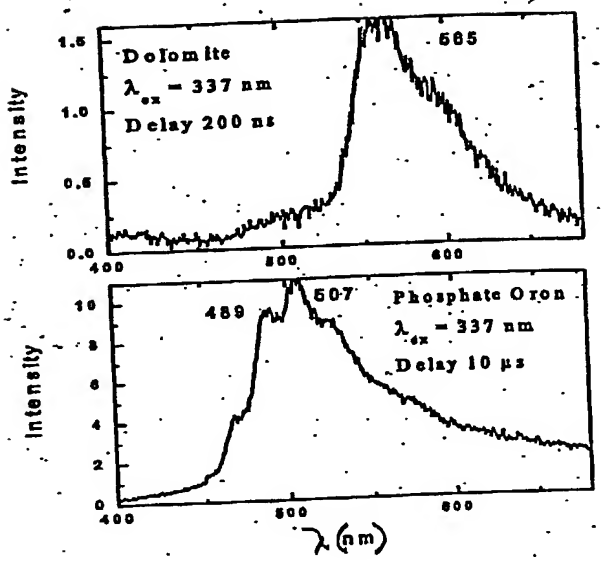
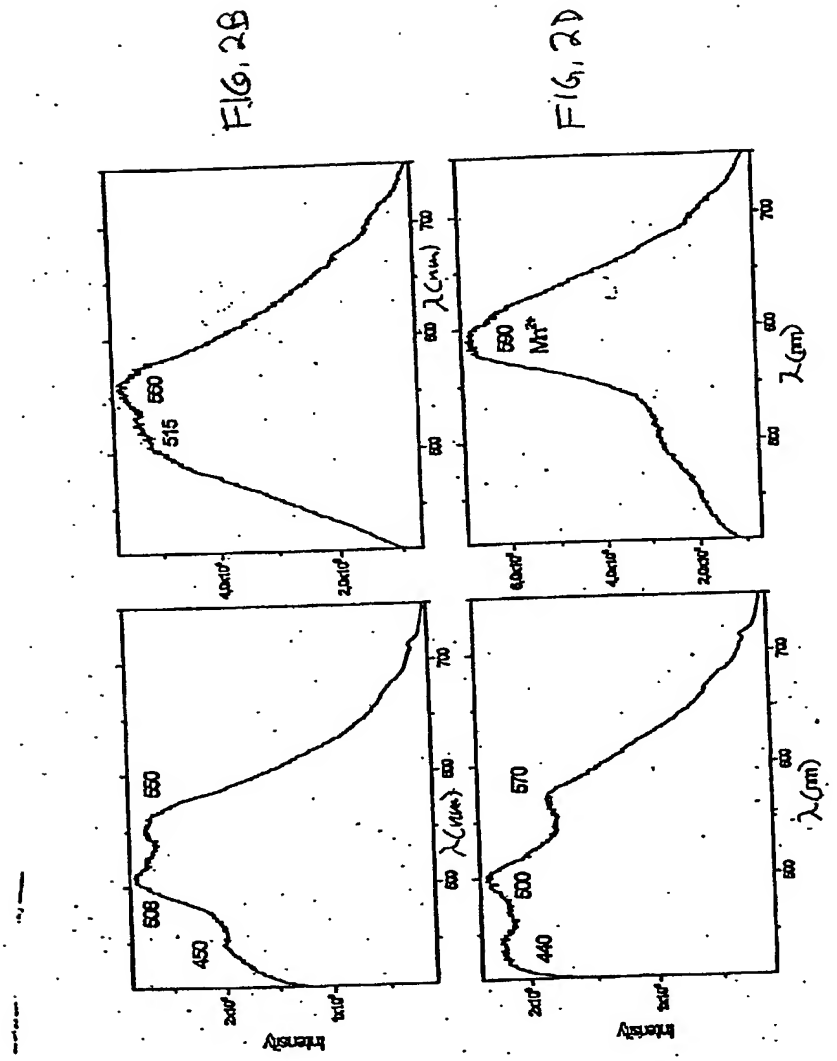
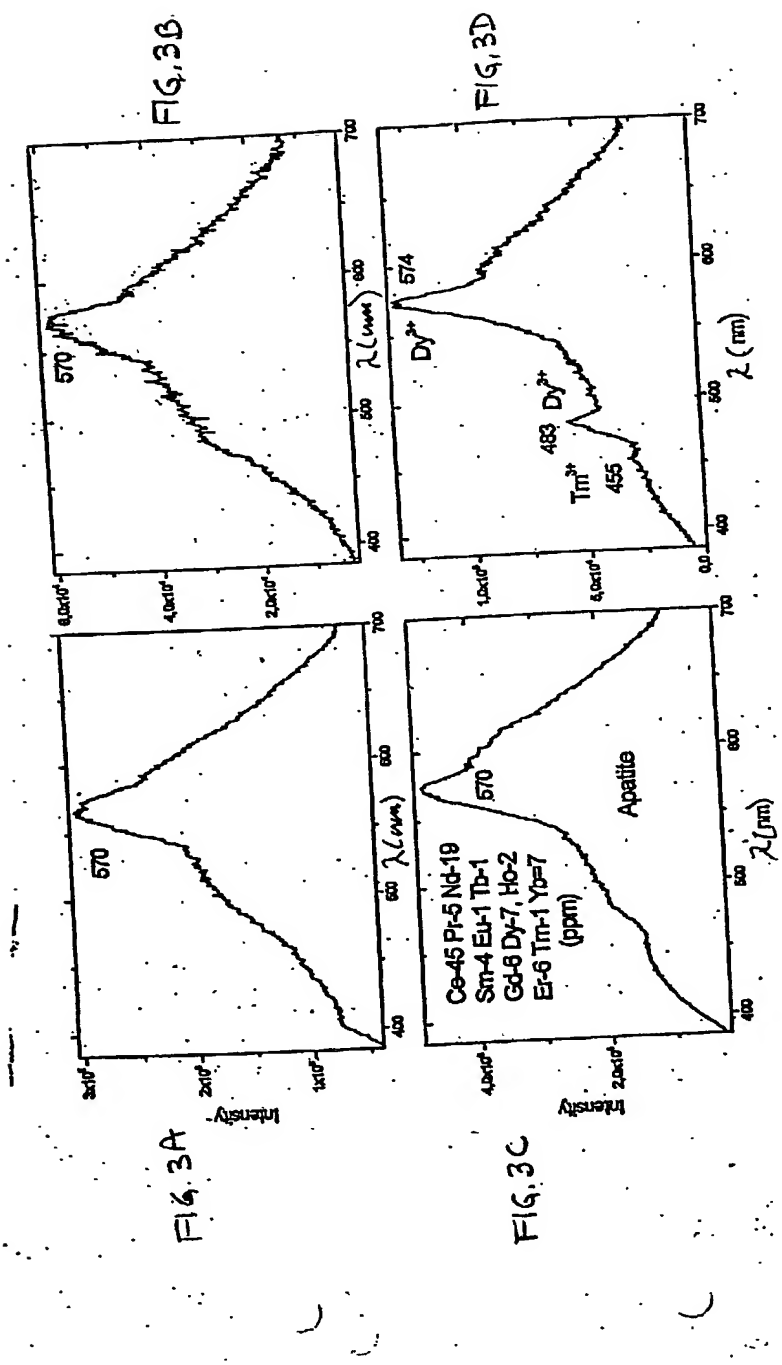
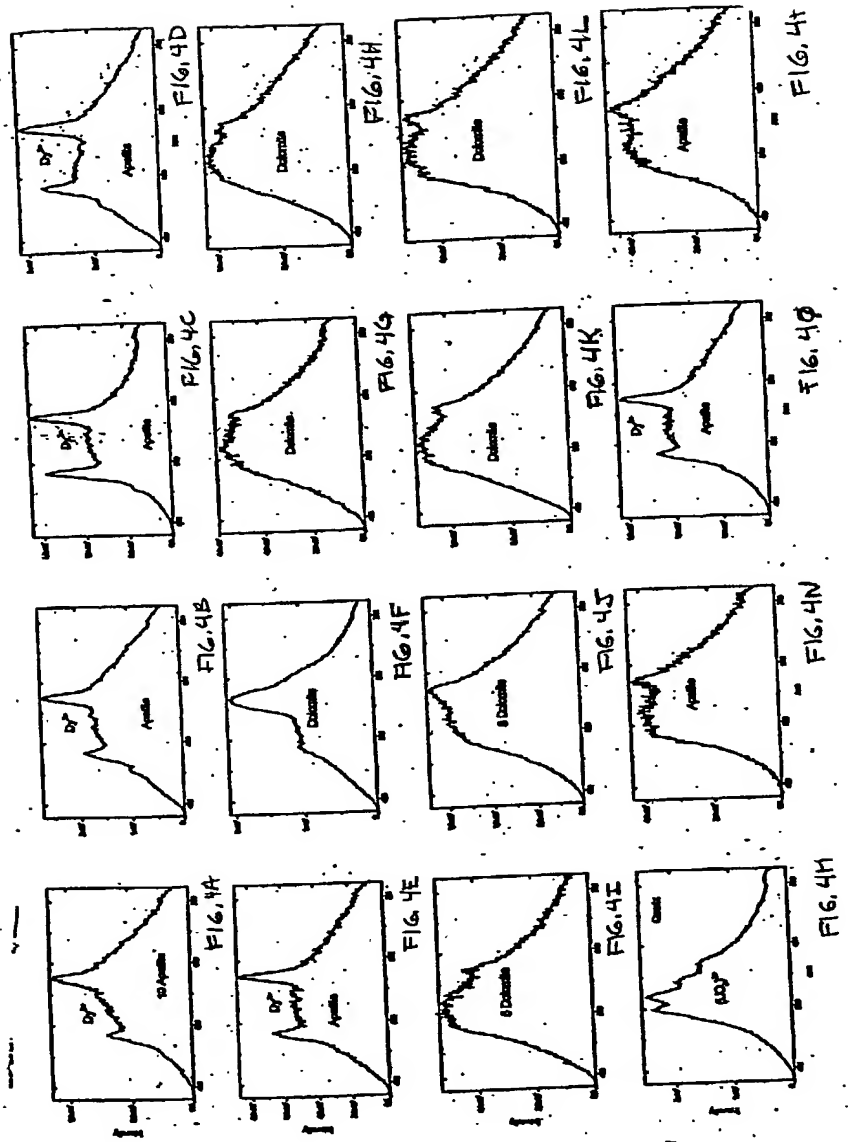
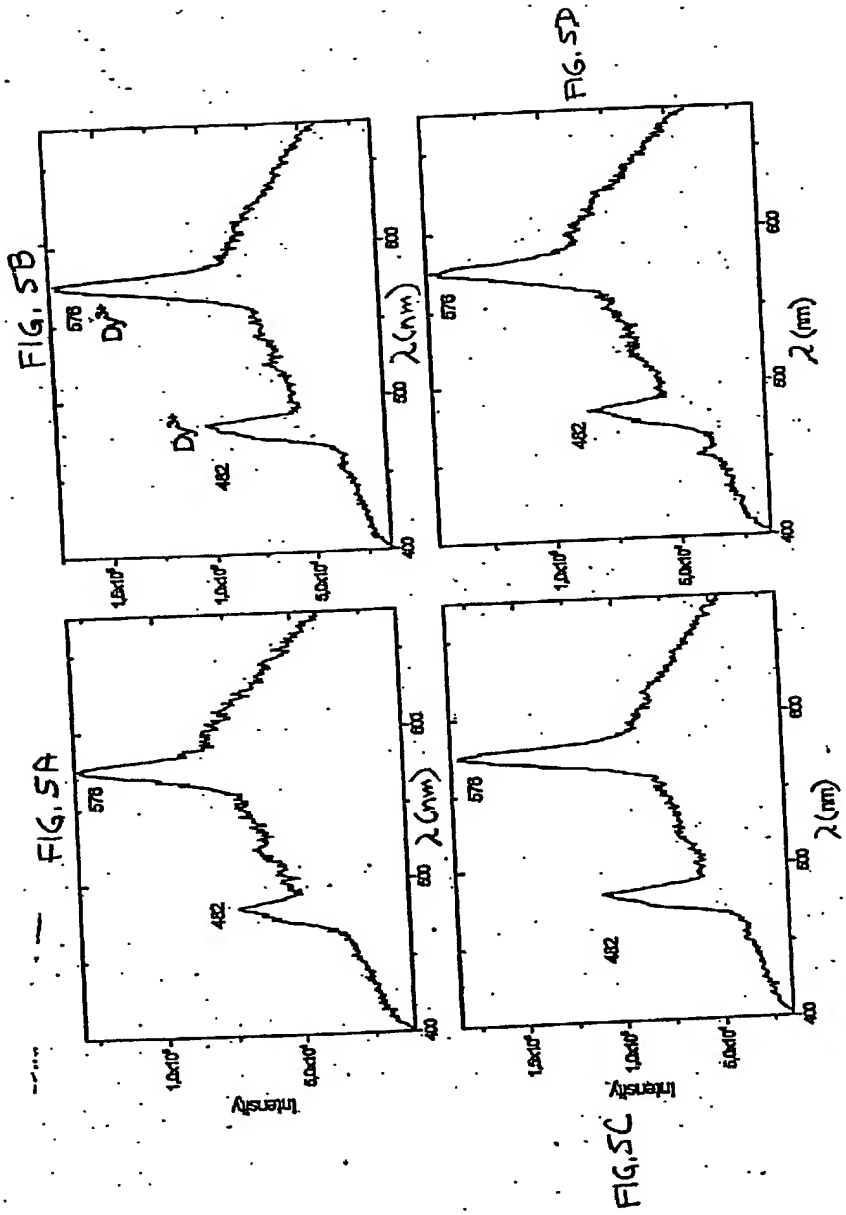

Dolomite
λ_{ex} = 337 nm
Delay 200 ns
685
Intensity
1.5
1.0
0.5
0.0
400
500
600
489
507
Phosphate Oron
λ_{ex} = 337 nm
Delay 10 µs
Intensity
10
8
6
4
2
0
400
500
600
λ (nm)

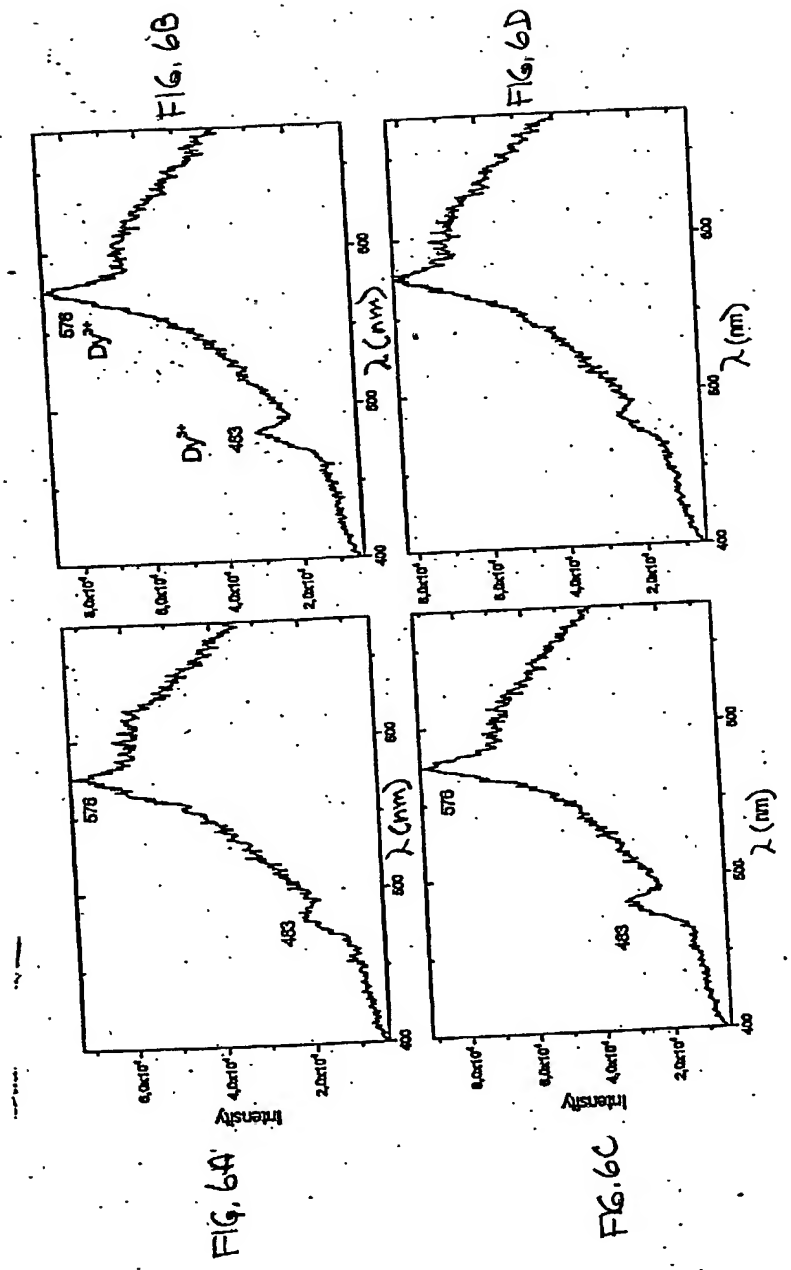
FIG. 1B


FIG, 2B
FIG, 2D
515
550
Mn2+
λ(nm)
Intensity
FIG, 2A
FIG, 2C
450
508
550
570
500
440


FIG,3B
570
λ(nm)
FIG,3D
574
Dy3+
483 Dy3+
Tm3+
455
λ (nm)
FIG,3A
570
Intensity
λ(nm)
FIG,3C
Ce-45 Pr-5 Nd-19
Sm-4 Eu-1 Tb-1
Gd-8 Dy-7, Ho-2
Er-6 Tm-1 Yb=7
(ppm)
570
Apatite
Intensity
λ(nm)


Dz°
Apatite
FIG. 4A
Dz°
Apatite
FIG. 4B
Dz°
Apatite
FIG. 4C
Dz°
Apatite
FIG. 4D
Dz°
Apatite
FIG. 4E
Dz°
Dolomite
FIG. 4F
Dz°
Dolomite
FIG. 4G
Dz°
Dolomite
FIG. 4H
Dz°
Dolomite
FIG. 4I
Dz°
Dolomite
FIG. 4J
Dz°
Dolomite
FIG. 4K
Dz°
Dolomite
FIG. 4L
Dz°
Calcite
FIG. 4M
Dz°
Apatite
FIG. 4N
Dz°
Apatite
FIG. 4O
Dz°
Apatite
FIG. 4P


FIG, 5A
FIG, 5B
FIG, 5C
FIG, 5D
Intensity
λ(nm)
λ(nm)
576
482
Dy3+
Dy3+
400
600
800
1,0x10^5
5,0x10^4


FIG, 6B
FIG, 6D
FIG, 6A
FIG, 6C
Dy3+
Dy3+
576
483
λ (nm)
Intensity

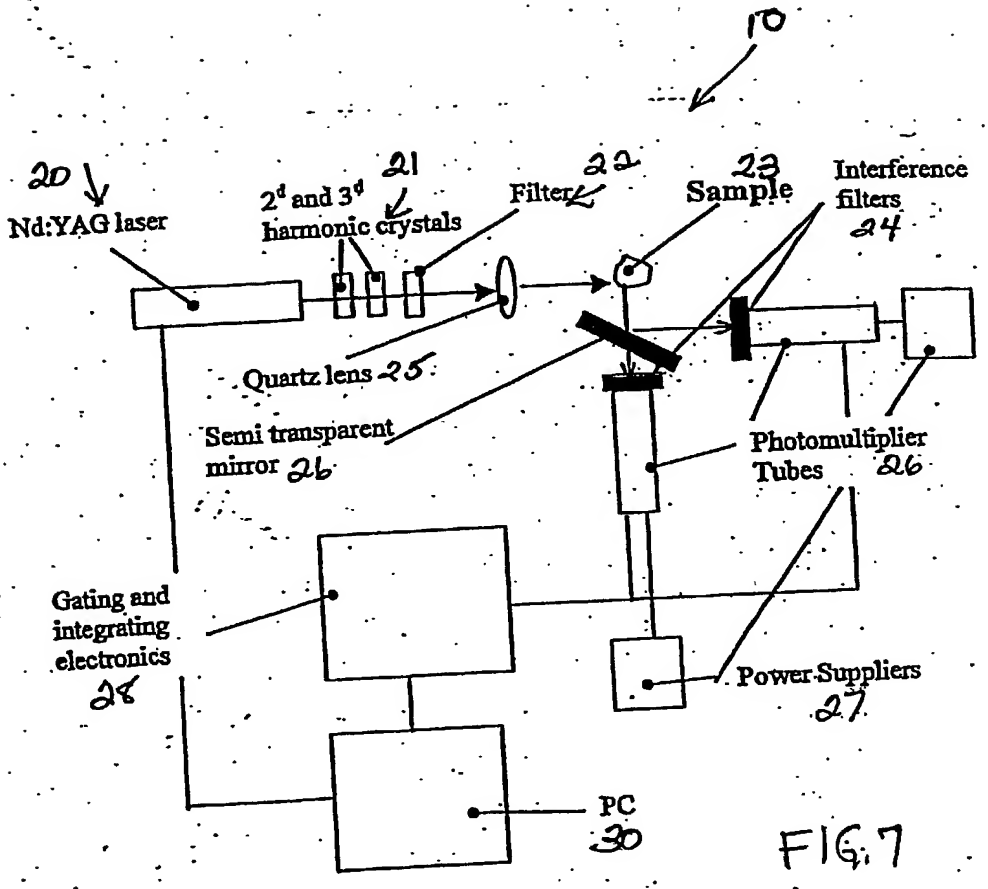
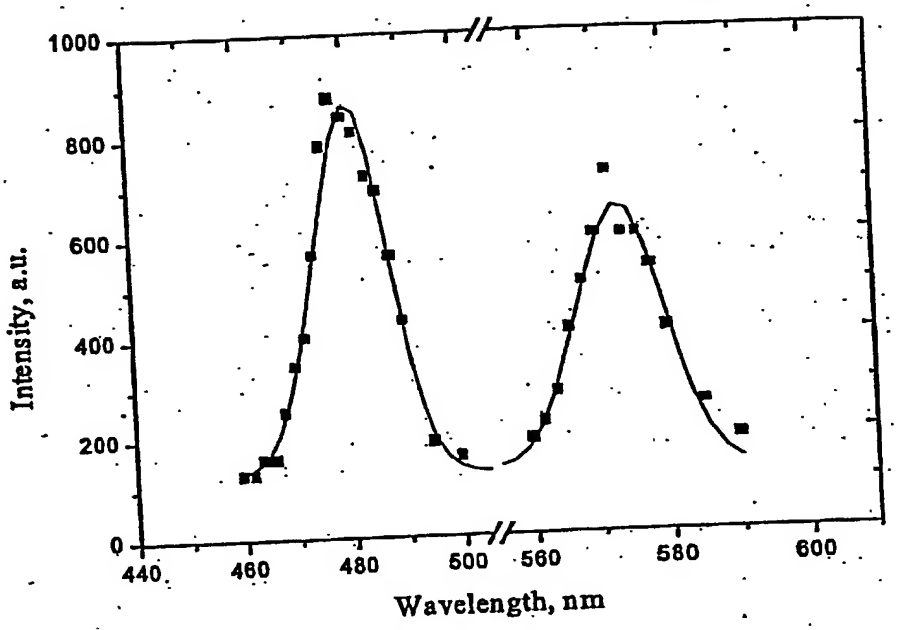

10
20
Nd:YAG laser
21
2d and 3d harmonic crystals
22
Filter
23
Sample
Interference filters
24
Quartz lens 25
Semi transparent mirror 26
Photomultiplier Tubes 26
Gating and integrating electronics 28
Power Suppliers 27
PC 30

FIG. 7

FIG. 8


1000
800
600
400
200
0
Intensity, a.u.
440
460
480
500
560
580
600
Wavelength, nm

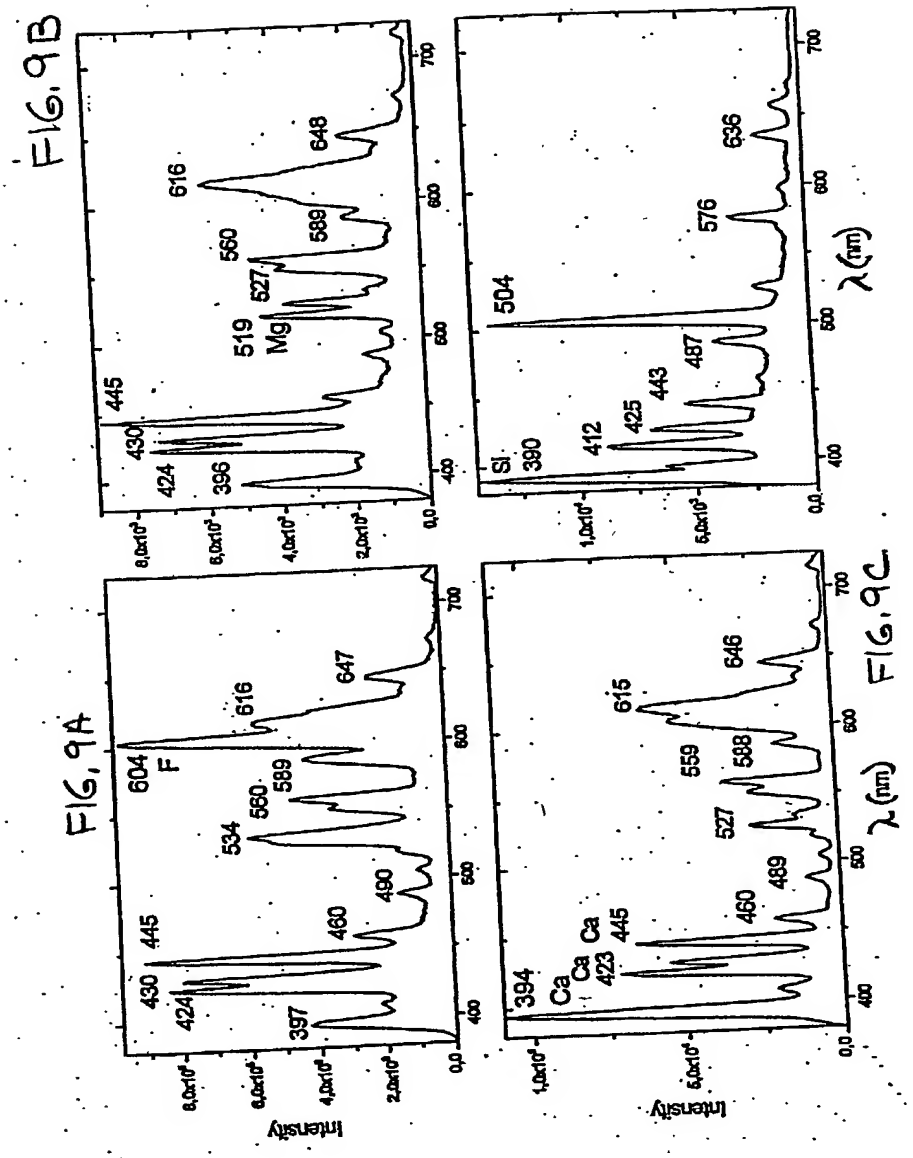

FIG, 9A
FIG, 9B
FIG, 9C
Intensity
λ (nm)
F
Mg
Ca
Ca
Ca
Si

FIG. 10A

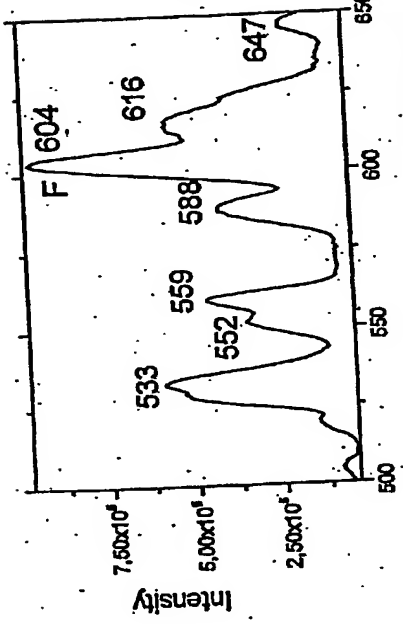
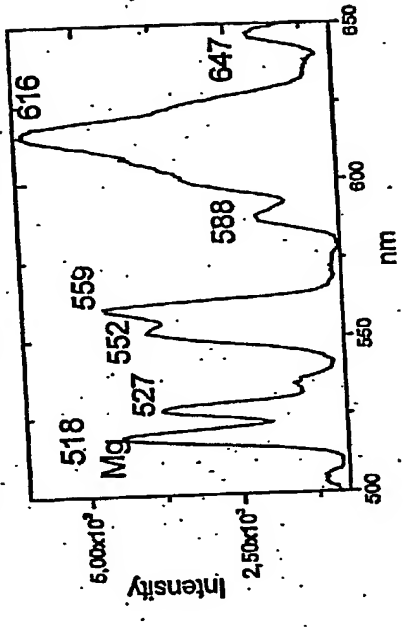


FIG. 10B



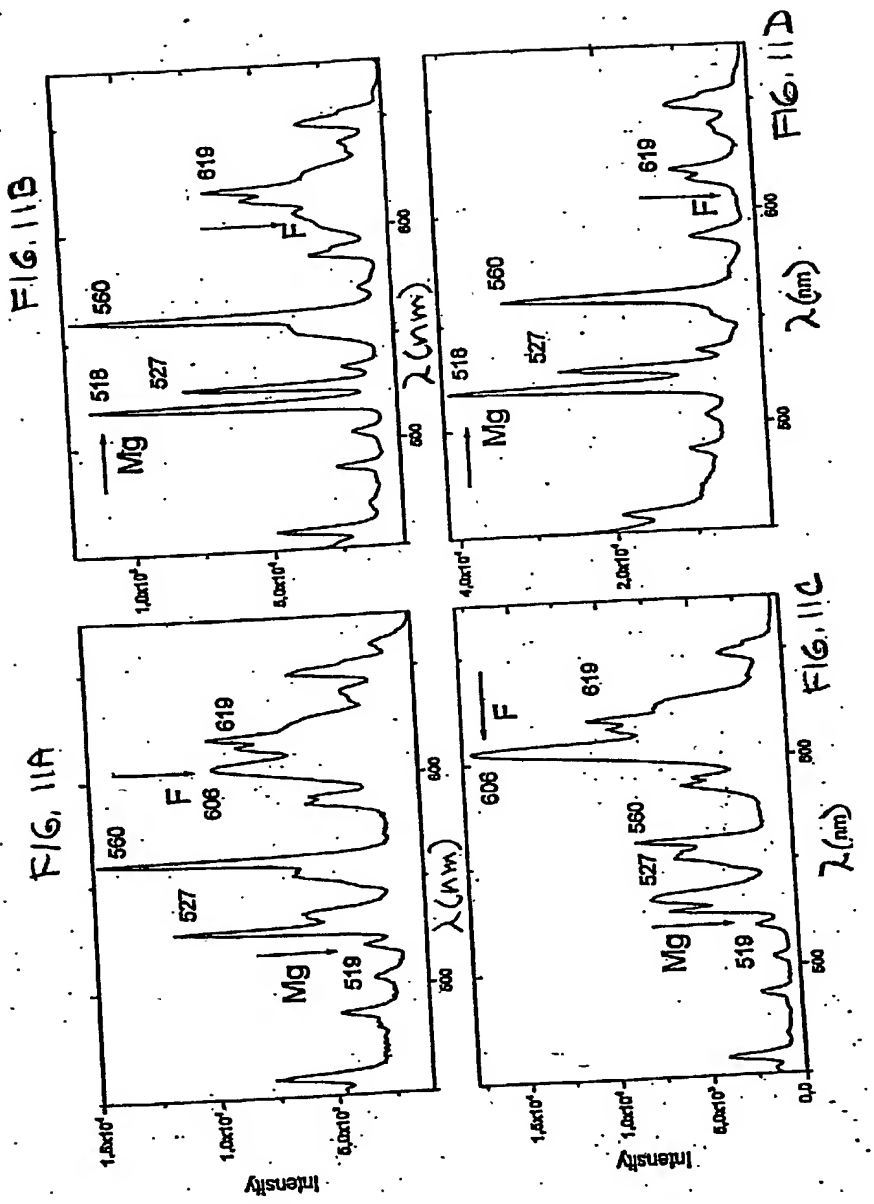


FIG. 11A
FIG. 11B
FIG. 11C
FIG. 11A
Intensity
λ(nm)
Mg
F
519
527
560
606
608
619
518

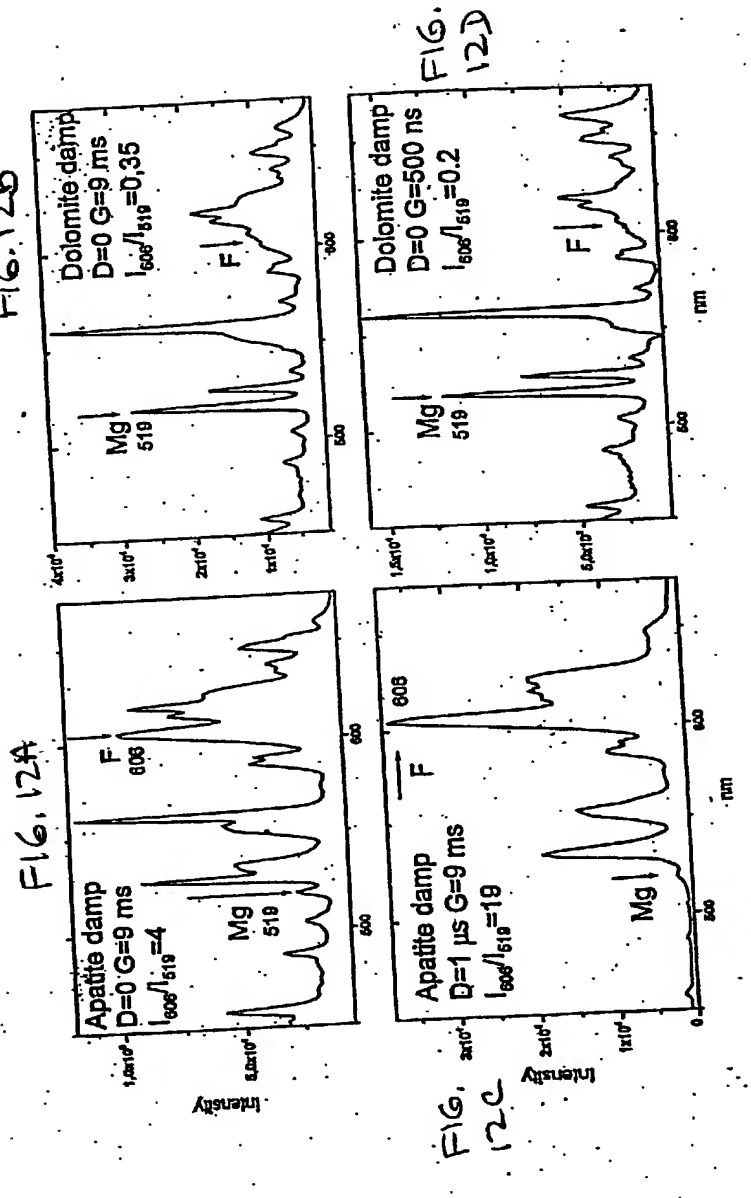


FIG. 12A

FIG. 12B

FIG. 12C

FIG. 12D

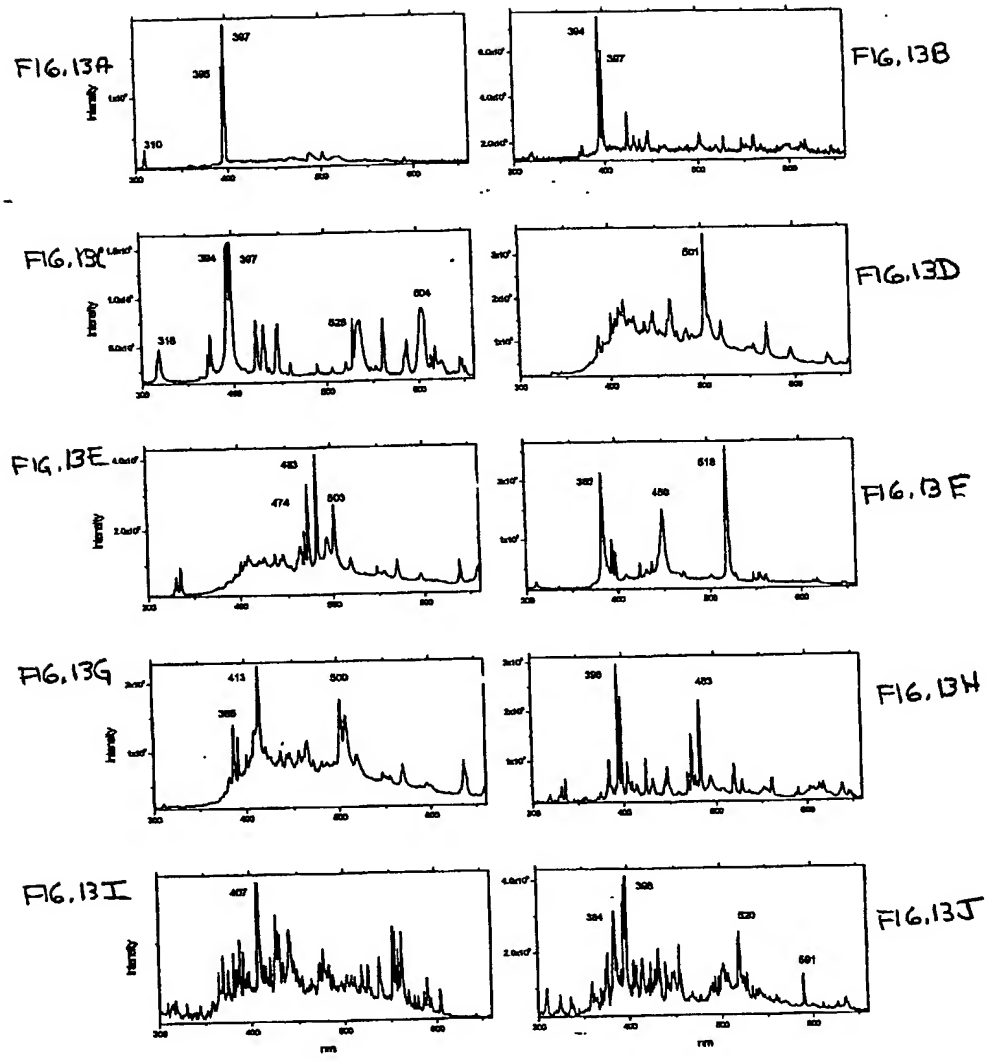


FIG. 13A
FIG. 13B
FIG. 13C
FIG. 13D
FIG. 13E
FIG. 13F
FIG. 13G
FIG. 13H
FIG. 13I
FIG. 13J
Intensity
nm

FIG. 14

Table 1

Rare-Earth Element Concentration in Florida Apatite

Determined by Inductively Coupled Plasma Method (ICP)

REE	Ce	Pr	Nd	SM	Eu	Tb	Gd	Dy	Ho	Er	Tm	Er	Yb
Ppm	45	4.5	19	4	1.2	1.0	6	7	1.7	5.6	0.9	5.6	6.8

FIG. 15

Table 2(a). I_{580}/I_{530} Distinguishing Features in Apatite and Dolomite Under 337 and 355 nm Excitation

Sampling	Color	Apatite %	Apatite with I_{580}/I_{530} %	Dolomite	Dolomite with I_{580}/I_{530} %	Apatite without I_{580}/I_{530} %
+ 1/2	white	41	67	59	0	33
	black	100		0		
+ 3/8	white	52	80	48	7	20
	black	83		17		
+ .156	white	63	80	37	0	20
	black	92		8		
+ 16	white	92	84	8	0	16
	black	100		0		
Kingsford	white	70	81	30	0	19
	black	100		0		
Fort Green	white	83	87	17	0	13
	black	92	9	8		

FIG. 16

Table 2(b). Dy^{3+} Distinguishing Features in Apatite and Dolomite Under 337 and 355 nm Excitation						
Sampling	Color	Apatite %	Apatite with Dy3+ %	Dolomite	Dolomite with Dy3+ %	Apatite without Dy3+ %
+ 1/2	white	41	67	59	0	33
	black	100		0		
+ 3/8	white	52	40	48	0	60
	black	83		17		
+ .156	white	63	80	37	0	20
	black	92		8		
+ 16	white	92	80	8	0	20
	black	100		0		
Kingsford	white	70	56	30	0	44
	black	100		0		
Fort Green	white	83	73	17	0	27
	black	92	9	8		

FIG. 17

Table 3. Chemical Analyses of the Products Received by LIBS									
	PITRLS	No. Pebbles	MgO	P_2O_5	BPL	F	Fe_2O_3	Al_2O_3	Insoluble
1	"Bad"	20	2.21	3.48	7.60	0.37	1.11	2.23	70.40
	"Good"	31	0.46	28.61	62.52	3.58	0.74	1.08	12.94
2	"Bad"	18	2.50	5.93	12.96	0.52	1.06	3.84	63.92
	"Good"	33	0.44	28.11	61.42	3.33	0.78	0.75	13.33
3	"Bad	13	4.6	4.49	9.81	0.3	1.27	2.01	56.46
	"Good"	45	0.34	27.37	59.80	3.42	0.76	1.42	14.24

FIG. 18

Table 4 shows LIBS analysis of the same samples.

Table 4. LIBS Data Using PMP Setup

Sample		I_{600}	I_{520}	I_{600}/I_{520}	Mineral
1/2	4	18.2	4.8	3.8	Apatite
1/2	5	6.4	3.2	2	Dolomite
1/2	6	11.6	6.6	1.8	Dolomite
1/2	7	15.6	2.1	7.8	Apatite
1/2	8	8.8	4.2	2.1	Dolomite
1/2	9	14.4	9	1.6	Dolomite
1/2	10	25	4.4	5.7	Apatite
1/2	12	10.6	1.7	6.2	Apatite
1/2	13	15.6	2.1	7.8	Apatite
1/2	14	11	2.5	4.4	Apatite
1/2	15	1.8	0.8	2.3	Apatite
3/8	9	7	4.6	1.5	Dolomite
3/8	10	19.4	3	6.5	Apatite
3/8	11	4.2	4.2	1	Dolomite
3/8	13	4.6	2.3	2	Dolomite
3/8	15	7.5	1.2	6.2	Apatite
3/8	16	11.4	1.4	8.1	Apatite
3/8	17	16	2.2	7.3	Apatite
3/8	18	19	3.6	5.3	Apatite
3/8	19	18	2.4	7.5	Apatite
3/8	20	13	1.6	8.1	Apatite